

**SEISMIC HAZARD ZONE REPORT FOR THE  
OXNARD 7.5-MINUTE QUADRANGLE,  
VENTURA COUNTY, CALIFORNIA**

**2002**



**DEPARTMENT OF CONSERVATION**  
*California Geological Survey*

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**SEISMIC HAZARD ZONE REPORT 052**

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OXNARD 7.5-MINUTE QUADRANGLE,  
VENTURA COUNTY, CALIFORNIA**

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## **EXECUTIVE SUMMARY**

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Oxnard 7.5-minute Quadrangle, Ventura County, California. The map displays the boundaries of Zones of Required Investigation for liquefaction over an area of approximately 55 square miles at a scale of 1 inch = 2,000 feet. No Zones of Required Investigation for earthquake-induced landslides exist in the Oxnard Quadrangle.

The Oxnard Quadrangle lies along the coastline in southwestern Ventura County. The on-land portion of the quadrangle consists of the coastal lowlands of the Oxnard Plain bordered by nearly 11 miles of beaches. Near the northern border of the quadrangle the Santa Clara River empties into the Pacific Ocean just south of the Ventura Marina. The County of Ventura, the cities of Oxnard, Ventura, and Port Hueneme and the U.S. Navy administer land use within the quadrangle. Except for residential and commercial development associated with the cities of Oxnard, Port Hueneme, and Ventura land use within the quadrangle consists mainly of farming.

The map is prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years.

The liquefaction zone covers almost the entire Oxnard Quadrangle except for the slopes north of the Santa Clara River in the northwestern corner. This is the result of shallow ground water and the presence of materials in the lowlands that are subject to liquefaction in the event of strong seismic shaking.

### How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the California Geological Survey's Internet page: <http://www.consrv.ca.gov/CGS/index.htm>

Paper copies of Official Seismic Hazard Zone Maps, released by CGS, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available for purchase from:

BPS Reprographic Services  
149 Second Street  
San Francisco, California 94105  
(415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at CGS offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**



# INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at <http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp>

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed CGS to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Zone Report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historical ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Oxnard 7.5-minute Quadrangle.

**Note:** *New information developed during the liquefaction evaluation of the Saticoy Quadrangle, which bounds the Oxnard Quadrangle on the north, required a small revision of the previously released official version of the Oxnard Quadrangle map. The revision of the Oxnard Quadrangle map triggered a new six-month preliminary review period. The revised Oxnard Quadrangle map became official on December 20, 2002.*

# **SECTION 1**

## **LIQUEFACTION EVALUATION REPORT**

### **Liquefaction Zones in the Oxnard 7.5-Minute Quadrangle, Ventura County, California**

**By  
Ralph C. Loyd**

**California Department of Conservation  
California Geological Survey**

#### **PURPOSE**

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by DMG in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at <http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp>

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing liquefaction hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee under the auspices of the Southern California Earthquake Center (SCEC).

The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of liquefaction analysis, evaluation, and mitigation techniques (SCEC, 1999). This text is also on the Internet at:

<http://www.scec.org/>

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Oxnard 7.5-minute Quadrangle. Section 3 (addressing potential ground shaking), completes the report, which is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996).

Additional information on seismic hazards zone mapping in California is on CGS's Internet web page: <http://www.consrv.ca.gov/CGS/index.htm>

## **BACKGROUND**

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, including the Oxnard Quadrangle.

## **METHODS SUMMARY**

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Existing geologic maps were used to provide an accurate representation of the spatial distribution of Quaternary deposits in the study area. Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill
- Construction of shallow ground-water maps showing the historically highest known ground-water levels
- Quantitative analysis of geotechnical data to evaluate liquefaction potential of deposits
- Information on potential ground shaking intensity based on DMG probabilistic shaking maps

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the State Mining and Geology Board (DOC, 2000).

## **SCOPE AND LIMITATIONS**

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the Oxnard Quadrangle consist mainly of low-lying shoreline regions, alluviated valleys, floodplains, and canyon floors. DMG's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

## **PART I**

### **PHYSIOGRAPHY**

#### **Study Area Location and Physiography**

The Oxnard 7.5-minute Quadrangle covers approximately 55 square miles in southwestern Ventura County. Local physiography consists of the coastal lowlands of the Oxnard Plain where the land ranges in elevation from sea level to about 115 feet. The Santa Clara River empties into the Pacific Ocean in the northwestern corner of the quadrangle just south of the Ventura Marina. Except for development associated with the cities of Oxnard, Port Hueneme, and Ventura, land use within the valley areas of the

quadrangle consists mainly of farming. The Ventura Freeway (U.S. 101) and State Highway 1 provide the major transportation routes through the quadrangle. Secondary access routes include, from east to west, Harbor Boulevard, Victoria Avenue, Ventura Road, Saviers Road, Rose Avenue, and Rice Avenue and, from north to south, Gonzales Road, 5th Street, Wooley Road, Channel Islands, Blvd, Pleasant Valley Road, and Hueneme Road. The County of Ventura, the cities of Oxnard, Port Hueneme, and Ventura and the U.S. Navy administer land use within the quadrangle.

## **GEOLOGY**

### **Bedrock and Surficial Geology**

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. William Lettis and Associates (2000) provided digital Quaternary geologic mapping for use in this study. This geologic map is presented as Plate 1.1. Nomenclature for labeling Quaternary geologic units followed that applied by the Southern California Areal Mapping Project [SCAMP] (Morton and Kennedy, 1989). Other sources of geologic information referenced in this study include McCoy and Sarna-Wojcicki (1978), Turner (1975), Turner and Mukae (1975), and Weber and others (1973).

As illustrated on Plate 1.1, Holocene sedimentary deposits cover the entire land surface of the Oxnard Quadrangle. The alluvial units are divided on the basis of their depositional environment and relative ages, which were established on the basis of geomorphic expression (Table 1.1). For the most part, the young Quaternary sediments in the Oxnard Quadrangle consist of sandy material deposited in alluvial fan, alluvial valley, and stream channel (wash) depositional environments associated with the Santa Clara River. This river-transported material was derived mainly from pre-Quaternary sandstone and sand-rich sedimentary bedrock and older Quaternary units exposed in the highland regions of northern Ventura and western Los Angeles counties. The only sedimentary deposits in the Oxnard Quadrangle not associated with the Santa Clara River (other than the beaches) form part of an alluvial fan exposed on the north side of the river. This fan is one of a series of coalescing fans formed along the base of the Ventura Hills.

At least three generations of young Quaternary depositional units are identified on Plate 1.1. The first generation consists of wash (Qw1), alluvial fan (Qyf1), and alluvial valley deposits of late Holocene age. The second consists of wash (Qw2), alluvial fan (Qyf2), and alluvial valley (Qya2) deposits of latest Holocene age. The third consists of wash (Qw) and alluvial fan (Qf) deposits of modern age.

Geologic Map Unit	Sediment Type	Environment of Deposition	Consistency	Susceptible to Liquefaction?*
Qw, Qw2, Qw1	Sandy, silty sand	stream channels	Loose	Yes
Qf	Sand, silty sand	active alluvial fans	Loose	Yes
Qyfl-2, Qya1-2	Silty sand, sand, minor clay	young alluvial fan and valley deposits	Loose to moderately dense	Yes
* When saturated.				

**Table 1.1. General Geotechnical Characteristics and Liquefaction Susceptibility of Quaternary Sedimentary Units.**

## ENGINEERING GEOLOGY

Standard Penetration Test (SPT) data provide a standardized measure of the penetration resistance of a geologic deposit and commonly are used as an index of density. Many geotechnical investigations record SPT data, including the number of blows by a 140-pound drop weight required to drive a sampler of specific dimensions one foot into the soil. Recorded blow counts for non-SPT geotechnical sampling, where the sampler diameter, hammer weight or drop distance differ from those specified for an SPT (ASTM D1586), were converted to SPT-equivalent blow count values and entered into the DMG GIS. The actual and converted SPT blow counts were normalized to a common reference effective overburden pressure of 1 atmosphere (approximately 1 ton per square foot) and a hammer efficiency of 60% using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as  $(N_1)_{60}$ .

Logs of more than 175 borehole test sites in the Oxnard Quadrangle were collected from the City of Oxnard, the County of Ventura, California Department of Transportation (CalTrans), and Fugro West, Inc. These data were then entered into DMG's Geographic Information System (GIS). Locations of all exploratory boreholes considered in this investigation are shown on Plate 1.2. Construction of cross sections using data reported on the borehole logs enabled staff to relate lithology and soil-engineering properties to the various depositional units, to correlate soil types from one borehole to another, extrapolate geotechnical data into outlying areas containing similar soils, and to evaluate ground-water conditions.

Turner (1975) shows the thickness of Holocene deposits to average between 200 and 250 feet throughout most of the Oxnard Plain. Borehole log data indicate that the initial 40 feet, from the land surface downward, of these young Quaternary sediments consists of alternating beds of sand, gravel, silt, and clay typical of basin alluviation. Lithologic descriptions, penetration tests, and dry density measurements recorded in the borehole logs and posted on computer-generated cross sections developed in this study show that loose sand and silty sand layers are particularly abundant in near-surface deposits

throughout the project area. In contrast, the sediments forming the alluvial fan north of the Santa Clara River, which is described above, are dominantly clayey material.

## **GROUND-WATER CONDITIONS**

Liquefaction hazard may exist in areas where depth to ground water is 40 feet or less. DMG uses the highest known ground-water levels because water levels during an earthquake cannot be anticipated because of the unpredictable fluctuations caused by natural processes and human activities. A historical-high ground-water map differs from most ground-water maps, which show the actual water table at a particular time. Plate 1.2 depicts a hypothetical ground-water table within alluviated areas.

Ground-water hydrology of the Oxnard Plain is summarized in reports by the California Department of Water Resources (1971), Turner (1975), Turner and Mukae (1975), and Densmore (1996). Near-surface ground water in the Oxnard Plain is associated with an unconfined aquifer extending from the surface to a depth of about 75 feet. This upper semi-perched ground-water zone is separated from deeper aquifers by clay-rich zone that averages over 80 feet in thickness. Borehole logs collected for this study indicate that the Oxnard Plain is marked by relatively consistent historical ground-water depths that range from 25 feet or more in the north central margin of the quadrangle to 0 feet along the coastline (Plate 1.2). Depth to ground water over most of the area covered by the Oxnard Quadrangle averages about 6 feet. Ground-water recharge in the Oxnard Plain originates mainly from surface and near-surface water flow of the Santa Clara River.

## **PART II**

### **LIQUEFACTION HAZARD POTENTIAL**

Liquefaction may occur in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction. Liquefaction opportunity is a function of the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their



mapping of liquefaction hazards in the Los Angeles region. This method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the State Mining and Geology Board (DOC, 2000). The Division of Mines and Geology (1976) also conducted an earlier study evaluating potential for liquefaction in the Oxnard Plain area.

### **LIQUEFACTION SUSCEPTIBILITY**

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment's geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps. DMG's qualitative relations between susceptibility, geologic map unit and depth to ground water are summarized in Table 1.1.

### **LIQUEFACTION OPPORTUNITY**

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such

purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in DMG's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Oxnard Quadrangle, peak accelerations of 0.54-0.67 g, resulting from earthquakes ranging in magnitude from 6.9 to 7.3, were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10% in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen, 1996). See the ground motion portion (Section 3) of this report for further details.

### **Quantitative Liquefaction Analysis**

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). Using the Seed-Idriss Simplified Procedure one can calculate soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The Seed-Idriss Simplified Procedure requires normalizing earthquake loading relative to a M7.5 event for the liquefaction analysis. To accomplish this, DMG's analysis uses the Idriss magnitude scaling factor (MSF) (Youd and Idriss, 1997). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where:  $FS = (CRR / CSR) * MSF$ . FS, therefore, is a quantitative measure of liquefaction potential. DMG uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures. The DMG liquefaction analysis program calculates an FS for each geotechnical sample for which blow counts were collected. Typically, multiple samples are collected for each borehole. The lowest FS in each borehole is used for that location. FS values vary in reliability according to the quality of the geotechnical data used in their calculation. FS, as well as other considerations such as slope, presence of free faces, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation.

Of the 175-plus geotechnical borehole logs reviewed in this study (Plate 1.2), 136 include blow-count data from SPT's or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2½-inch inside-diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (e.g. soil density, moisture content, sieve analysis, etc.) required for an ideal Seed-Idriss Simplified Procedure. For boreholes having acceptable penetration tests, liquefaction

analysis is performed using recorded density, moisture, and sieve test values or using averaged test values of similar materials.

## **LIQUEFACTION ZONES**

### **Criteria for Zoning**

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes
2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated
3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable
4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

- a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or
- b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or
- c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the Oxnard Quadrangle is summarized below.

### **Areas of Past Liquefaction**

Excerpts of 1858 topographic survey reports (California Division of Mines and Geology, 1976) describe ground lurch cracks and related features associated with liquefaction observed in the Santa Clara River a few miles south of the City of San Buena Ventura. In addition, numerous lurch cracks and sand-boil craters were reported and photographed in the bed of nearby Calleguas Creek (Pt. Mugu and Camarillo quadrangles) following the offshore February 1973 Point Mugu earthquake of magnitude 5.9 (California Division of Mines and Geology, 1976). Liquefaction features such as sand boils, lurch cracks, and "mud volcanoes" were also noted in Mugu Lagoon just a few miles southeast of the quadrangle boundary (Morton and Campbell, 1973). It is probable that widespread damage to buildings and other structures in Oxnard and the Point Mugu Naval Station caused by the 1973 earthquake were due in part to liquefaction and associated unstable soil conditions. Immediately following the January 17, 1994 Northridge earthquake liquefaction-related ground-failure features, including sand boils and lateral spreading cracks, were mapped by Barminski and others (1994) near the mouth of the Santa Clara River. The features were described as occurring parallel or subparallel to the shoreline and were observed in active floodplain and estuarine deposits less than 3 feet above mean high tide (Barminski and others, 1994).

### **Artificial Fills**

In the Oxnard Quadrangle, artificial fill areas large enough to show at the scale of mapping consist of engineered fill for drainage levees and elevated freeways. Since these fills are generally considered to be properly engineered, zoning for liquefaction in such areas depends on soil conditions in underlying strata.

### **Areas with Sufficient Existing Geotechnical Data**

In general, sufficient geotechnical data exist throughout the Oxnard Quadrangle to evaluate potential for liquefaction. The available borehole log data clearly indicate that young Quaternary sediments deposited in the upper 40 feet of the Oxnard Plain are composed predominantly of saturated, loose, sandy soils that are highly susceptible to liquefaction. The near-surface alluvial fan deposits north of the Santa Clara River are dominated by clayey material except in the Montalvo Mounds area and the marina where soil is sandy. Consequently, the entire land surface of the Oxnard Quadrangle south of the Santa Clara River valley is zoned as an area of required investigation for liquefaction.

### **Areas with Insufficient Existing Geotechnical Data**

As stated above, sufficient geotechnical data exist in the Oxnard Quadrangle to adequately evaluate potential for liquefaction. Therefore, it was not necessary to apply SMGB zoning criteria for areas with insufficient geotechnical data.

## ACKNOWLEDGMENTS

Thanks to Christopher Hitchcock of William Lettis and Associates for providing original mapping of Quaternary geology of the Oxnard Quadrangle. Appreciation is also extended to managers and staff of the City of Oxnard, Ventura County Public Works Agency, Ventura County Environmental Health Division, California Department of Transportation (CalTrans), California Department of Toxic Substances Control, and Fugro West, Inc., for providing geotechnical data that were critical to the successful completion of this study.

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## **SECTION 2**

# **EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT**

### **NO LANDSLIDE HAZARDS ZONED**

Within the Oxnard Quadrangle, no areas have been designated as “zones of required investigation for earthquake-induced landslides.” However, the potential for landslides may exist locally, particularly along stream banks, margins of drainage channels, and similar settings where steep banks or slopes occur. Such occurrences are of limited lateral extent or are too small and discontinuous to be depicted at 1:24,000 scale (the scale of Seismic Hazard Zone Maps). Within the liquefaction zones, some geologic settings may be susceptible to lateral-spreading (a condition wherein low-angle landsliding is associated with liquefaction). Also, landslide hazards can be created during excavation and grading unless appropriate techniques are used.



## **SECTION 3**

# **GROUND SHAKING EVALUATION REPORT**

### **Potential Ground Shaking in the Oxnard 7.5-Minute Quadrangle, Ventura County, California**

**By**

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Charles R. Real, and Michael S. Reichle**

**California Department of Conservation  
California Geological Survey**

**\*Formerly with CGS, now with U.S. Geological Survey**

#### **PURPOSE**

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at <http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp>

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided

herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions *for the analysis of ground failure* according to the “Simple Prescribed Parameter Value” method (SPPV) described in the site investigation guidelines (California Department of Conservation, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 (addressing liquefaction hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG’s Internet homepage: <http://www.consrv.ca.gov/CGS/index.htm>

## EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

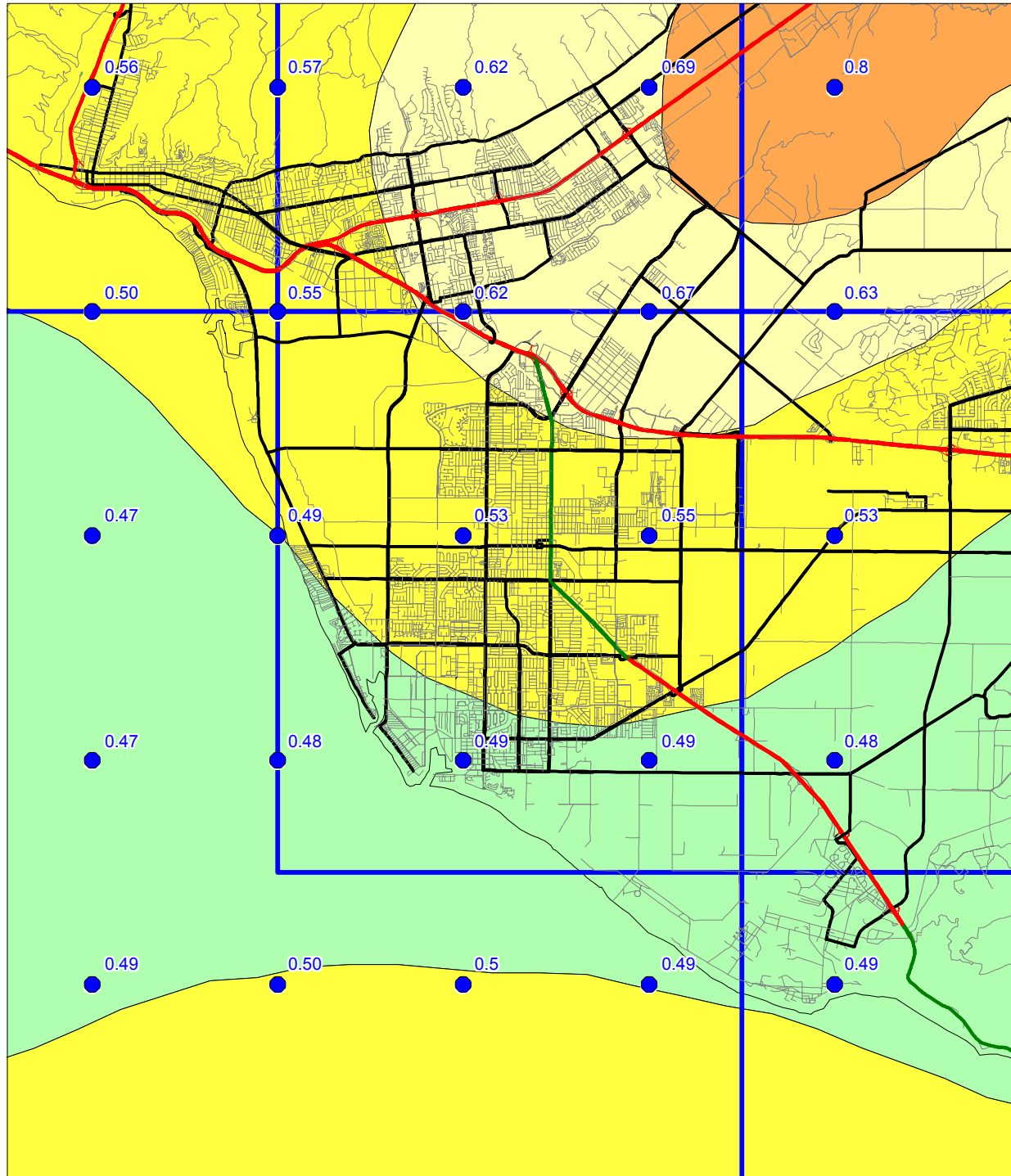
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent

# OXNARD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map from GDT

0 1.5 3  
Miles

Department of Conservation  
Division of Mines and Geology



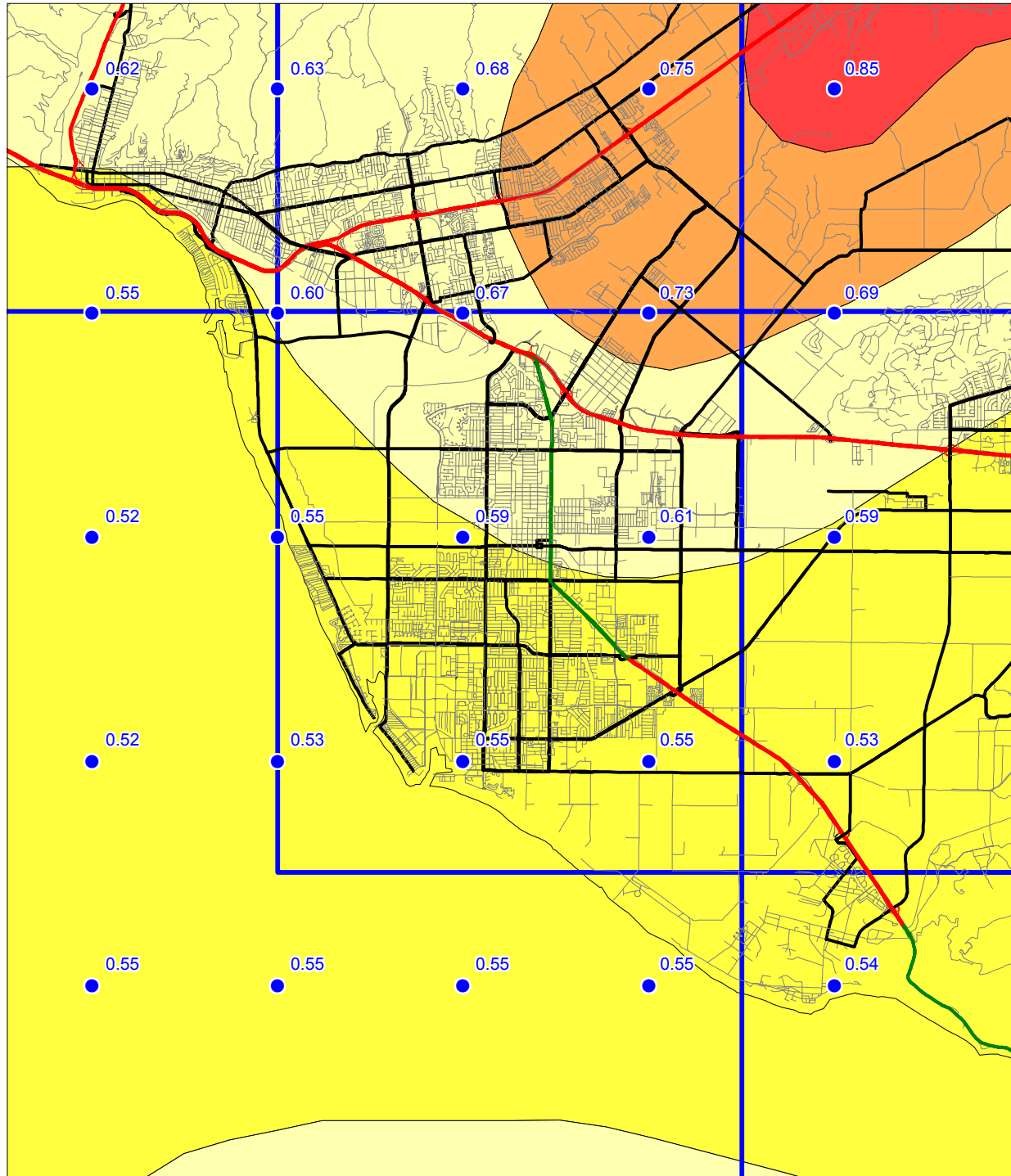
Figure 3.1

# OXNARD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION ( $g$ )

1998

**SOFT ROCK CONDITIONS**



Base map from GDT

0 1.5 3  
Miles

Department of Conservation  
California Geological Survey

Figure 3.2

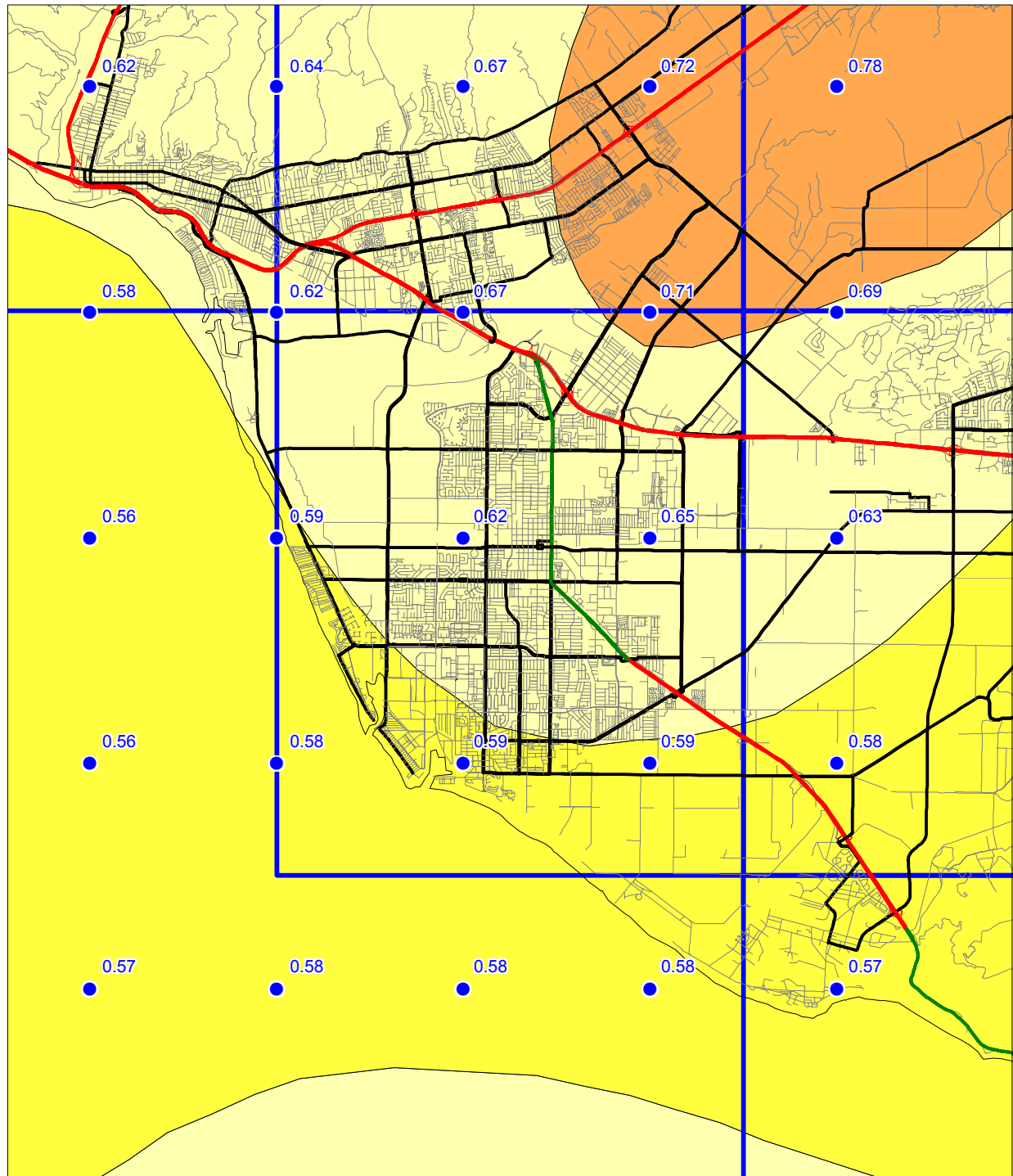


# OXNARD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

## ALLUVIUM CONDITIONS



Base map from GDT

0 1.5 3  
Miles

Department of Conservation  
California Geological Survey

Figure 3.3



quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

### APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

A preferred method of using the probabilistic seismic hazard model and the “simplified Seed-Idriss method” of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a “magnitude-weighted” ground motion (liquefaction opportunity) map that can be used directly in the calculation of the cyclic stress ratio threshold for liquefaction and for estimating the factor of safety against liquefaction (Youd and Idriss, 1997). This can provide a better estimate of liquefaction hazard than use of predominate magnitude described above, because all magnitudes contributing to the estimate are used to weight the probabilistic calculation of peak ground acceleration (Real and others, 2000). Thus, large distant earthquakes that occur less frequently but contribute *more* to the liquefaction hazard are appropriately accounted for.

Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss’ weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1) applied.

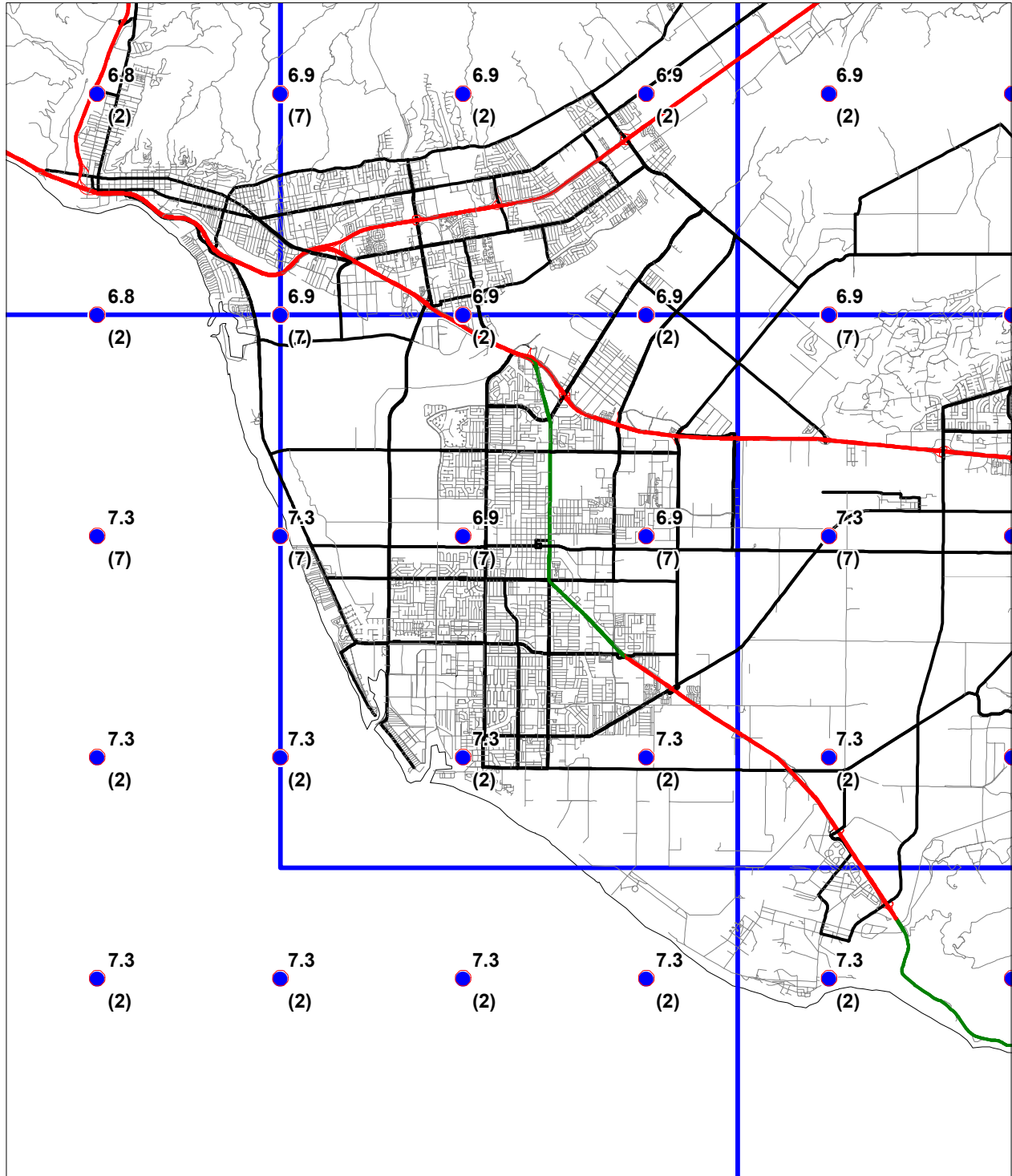


OXNARD 7.5 MINUTE QUADRANGLE AND PORTIONS OF  
ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

## PREDOMINANT EARTHQUAKE

Magnitude (Mw)  
(Distance (km))

Base map from GDT

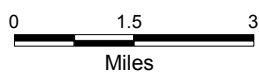
Department of Conservation  
California Geological Survey

Figure 3.4

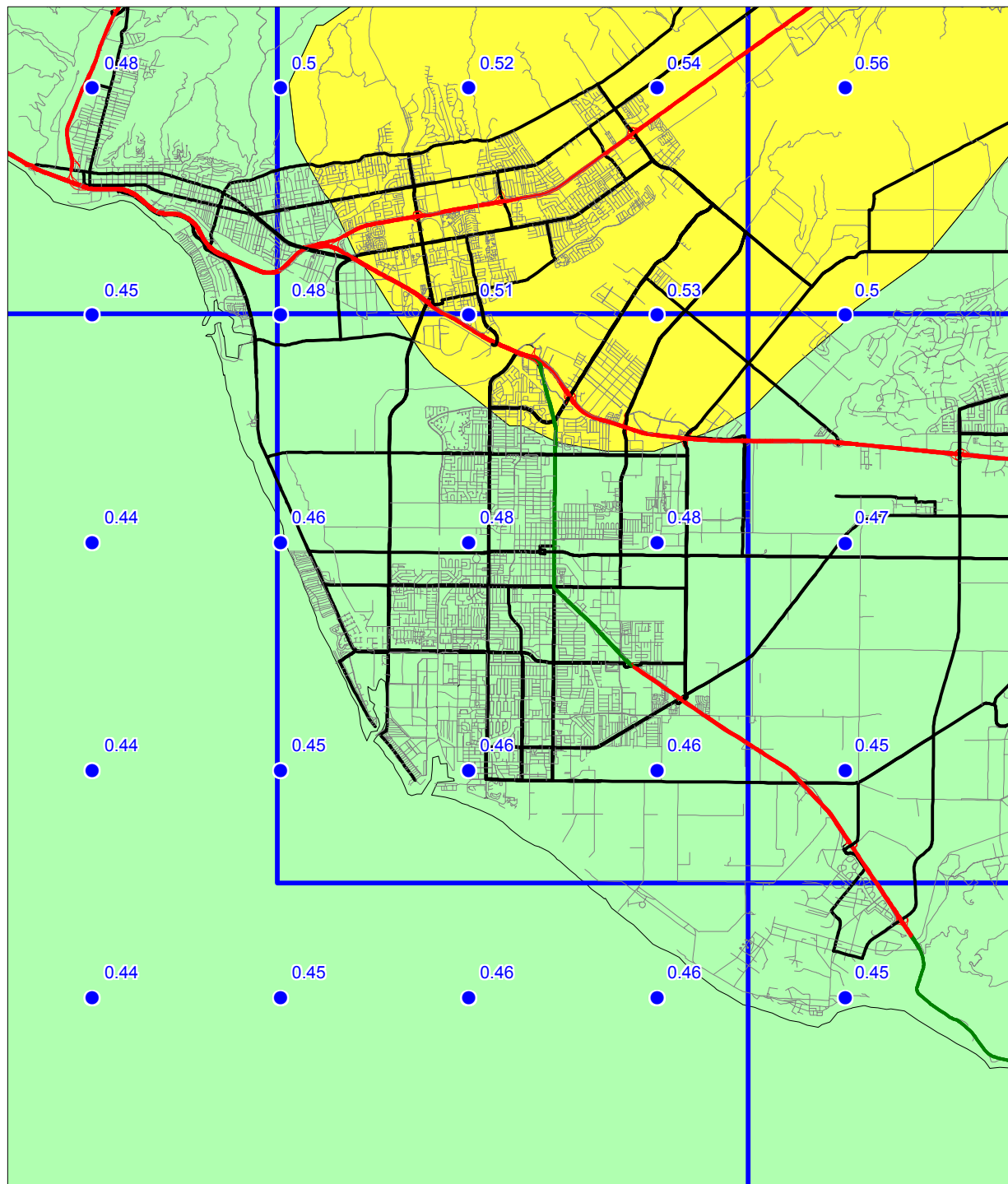


# OXNARD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g)  
FOR ALLUVIUM

2001

## LIQUEFACTION OPPORTUNITY



Base map from GDT

0 1.5 3  
Miles

Department of Conservation  
California Geological Survey



Figure 3.5



## USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.
2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours.*
3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).
4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not been previously recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.
5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

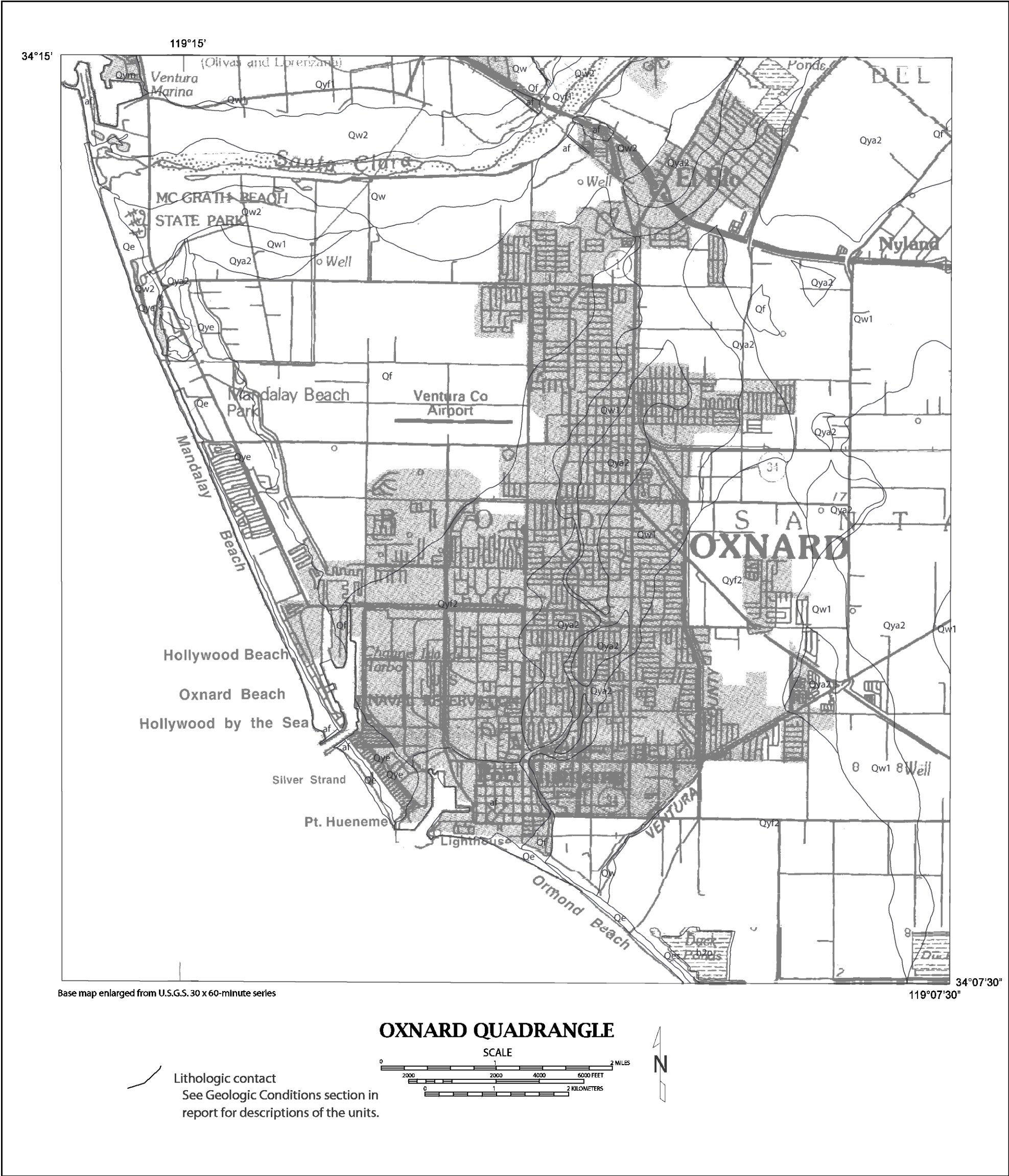
Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the

recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the “importance” or sensitivity of the proposed building with regard to occupant safety.

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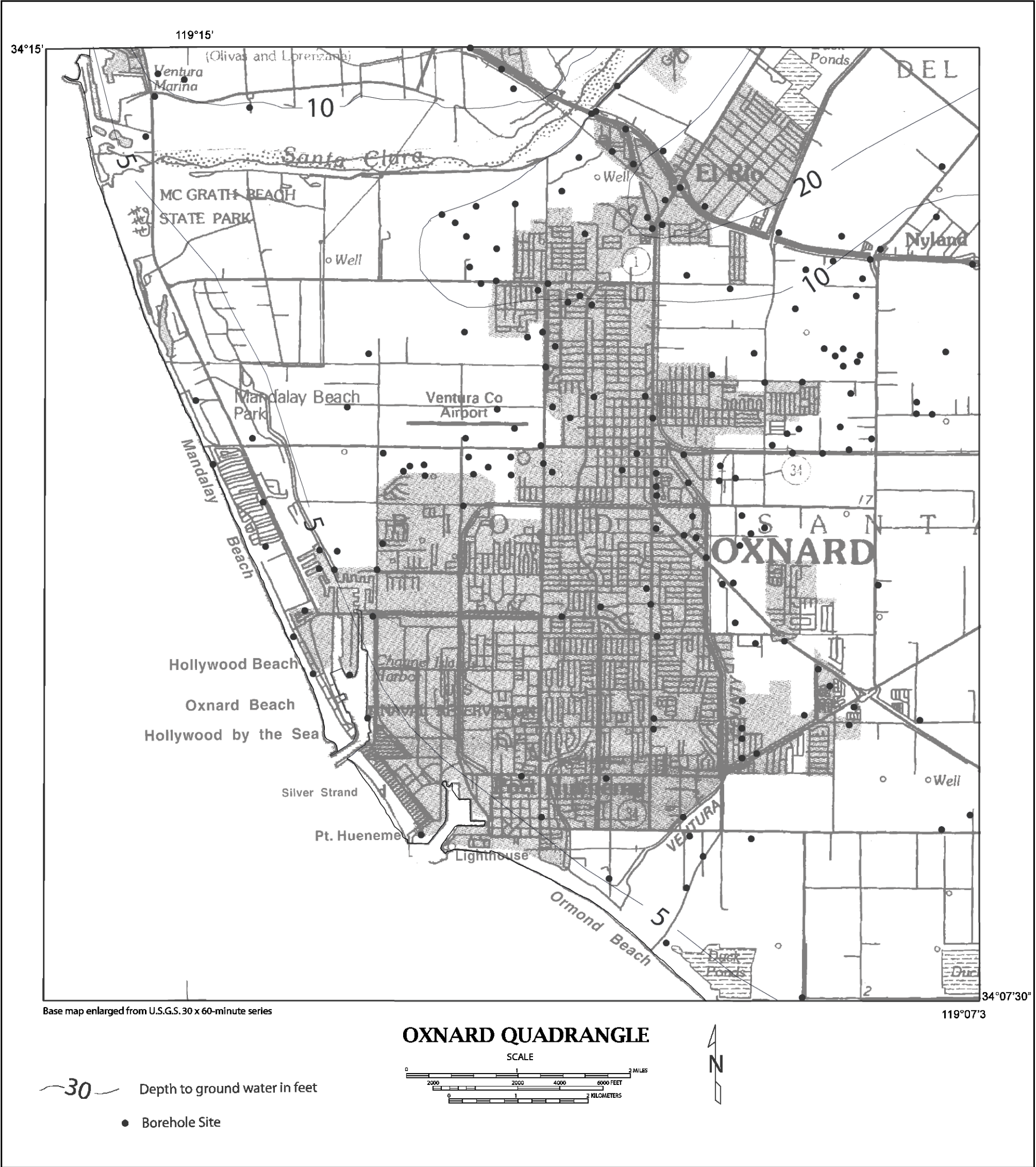


Plate 1.2 Depth to historically highest groundwater and borehole locations, Oxnard 7.5-minute quadrangle, California